

# PATENT SPECIFICATION

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## DRAWINGS ATTACHED

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## (54) METHOD OF CONSOLIDATING EARTH FORMATIONS WITHOUT REMOVING TUBING FROM WELL

(71) We, CHEVRON RESEARCH COMPANY, a corporation lawfully organized under the laws of the State of Delaware, United States of America, and having offices at 200 Bush Street, San Francisco, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of removing sand from a cased well having a production tubing located therein and preventing further sanding of the well without removing the production tube by means of inserting a flushing tube into the production tube and circulating out sand from the well, then packing off the flushing tube and injecting a series of sand consolidating fluids including a permeability levelling fluid through the flushing tube down the well and into the formation to consolidate the formation.

A serious problem is often caused during production of oil from wells by sand entering the well with the production fluids and accumulating to a point where production from the well is hindered or even halted because of the sand in the well. In many wells sand entering the well with the production fluids is also undesirable because of the damage that the sand can cause to the tubing and surface equipment by abrasion. Many techniques of sand consolidation have heretofore been practiced to control the flow of sand into wells. For example, methods of sand consolidation are described in U.S. Patents 3,176,767, 3,176,768 and 3, 176,769. Generally, these sand consolidation techniques are accomplished by injecting a resin into the formation and by consolidating the resin to hold the sand grains in place. These techniques require careful placement of the resin to insure adequate coverage over the entire treated interval. This usually limits the techniques to thin zones or

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requires that the consolidation fluids be injected into the formation by special tools. These special tools have a diameter approaching the diameter of the casing in which they are used.

The production tubing must be removed from the hole while removing sand and running these special tools since, as noted, the diameter of the tools approaches the diameter of the casing. There is need, therefore, for a method of removing sand from a well and preventing further sanding of the well in which a casing and a production tubing are located without removing the production tubing from the well. This is particularly true in deep offshore wells where pulling the tubing constitutes a major operation.

There is a serious problem in consolidating unconsolidated formations penetrated by a well because of the non-uniform permeability distribution that almost always occurs in such formations. This problem is particularly troublesome where, for space or other reasons, injection tools cannot be used since these tools are necessarily near full bore size to permit casing pack-off. There is need, therefore, for a method of removing sand from a well and then consolidating the formation producing the sand without need of removing tubing from the well and in such a manner to insure that the distribution of sand consolidation fluids in such formation is relatively even.

In our pending Application No. 25494/69 (Serial No. 1,252,312) (to which the present application is an addition) there is described a method of consolidating an incompetent earth formation having strata of different permeability wherein a liquid resin curable to a solid infusible state is injected into the formation, characterised in that there is injected into the formation prior to the injection of the resin a cellulosic permeability levelling material in a liquid carrier and that said cellulosic permeability levelling material is caused to contact the strata of different permeability

to assist in providing more nearly equal permeability distribution in said sand formation for the later injection of said resin.

According to the present invention, there is provided a method of removing sand from a well penetrating an unconsolidated formation and preventing further sanding of the well, the well having a casing and a production tube located therein, without removing the production tube from the well, said method comprising the steps of packing off the annulus between the well casing and the production tube, positioning a flushing tube inside the production tube to form an annular passage between the flushing tube and the production tube, circulating a fluid in the flushing tube and said annular passage to remove sand from the well, closing off the annular passage, injecting a cellulosic permeability levelling material down the flushing tube and into said formation to assist in levelling the injection profile of said formation, thereafter injecting one or more sand consolidation fluids down the flushing tube and into the formation to consolidate sand in the formation and thereby prevent further sanding of the well, and then removing the flushing tube from the production tube.

The present invention provides for consolidating a formation penetrated by a cased well having a production tube located therein without removing the production tube from the well and completing such consolidation in such a manner to provide for relatively uniform placement of the consolidation fluids in the well to insure a successful operation. In accordance with the invention, a flushing tube of smaller diameter than the production tube is inserted into the production tube and down the well. The outer diameter of the flushing tube is such that an annulus is formed between the production tube and the flushing tube. The flushing tube is lowered to approximately the sand level in the well and a fluid is circulated to remove sand from the well. Circulation may occur down the flushing tube and up the annulus between the flushing tube and the production tube. Alternatively circulation may be down the annulus and up the flushing tube. After the sand in the well has been removed by such circulation the annulus between the production tube and the flushing tube is packed off. This pack off is usually accomplished by closing in the annulus at the surface. Usually it is then necessary to inject a slurry of specially selected sand in a fluid down the flushing tube and out into the formation to replace the formation sand previously produced. After the injected sand has been located in the formation, a cellulosic permeability levelling material is injected down the flushing tube and out into the formation to provide for more uniform placement of the later injected sand consolidation fluids. The cellulosic permeability levelling material is carried

in a liquid carrier to facilitate its injection through the flushing tube. After such permeability levelling material is in place in the formation, sand consolidation fluids are then injected down the flushing tube and into the formation to consolidate the sand in the formation to prevent further sanding of the well.

More specifically the invention provides in a preferred embodiment thereof for injecting down the flushing tube and into the formation a cellulosic permeability levelling mixture comprising a mixture of 100 parts by volume of a hydrocarbon oil, from 15 to 35 parts by volume of a selected low molecular weight alkanol and from 0.005 to 0.25 parts by weight of a cellulosic permeability levelling compound per 100 parts by weight of the above mixed liquids. After such permeability levelling material is located in the formation sand consolidation fluids are sequentially passed down the flushing tube and into the formation. Such sand consolidation fluid sequentially includes a liquid resinous material curable to an infusible solid state by treating with a curing agent: a liquid hydrocarbon and a curing agent to convert the liquid resinous mixture to the infusible solid state to consolidate the sand in the formation adjacent the well.

It is a particular object of the present invention to provide a method of sand consolidation for use in consolidating sand in a well having a casing and a production tubing located therein without removing the production tubing from the well. Further objects and advantages of the present invention will become apparent from the following detailed description read in light of the accompanying drawing in which:

Figure 1 is a sectional view of a cased well having a production tube located therein, said well penetrating a producing formation which has sanding up the well;

Figure 2 is a sectional view and shows a flushing tube located in said well for use in circulating undesirable sand from the well;

Figure 3 is a sectional view and shows a flushing tube located in said well for use in sand packing of the clean-out well;

Figure 4 is a sectional view and shows a flushing tube located in a well for use in injecting sand consolidation fluids into the sand packed well; and

Figure 5 is a sectional view and shows said well ready to return to production.

Referring now to Figure 1, a well 20 is shown penetrating various nonproductive earth strata 22 and 24 and a producing strata or zone 26. The well is cased over the non-productive intervals 22 and 24 by means of suitable casing 28. A production liner 30 having slots 32 is used to line the well adjacent the oil producing zone 26. Alternatively, the well may be cased over its entire depth and

the producing intervals perforated. Production tubing 34 extends down the well to the vicinity of producing zone 26 for production of fluids therefrom. The annulus 36 between the well casing 28 and the production tubing 34 is packed off by suitable means such as a production packer 38. Thus well fluids are produced up production tubing 34. As known in the art, production may be by natural flow or production may be assisted by artificial means such as by pumping or gas lift. As illustrated schematically in Figure 1, sand particles 40 from formation 26 have entered the well through the slots 32 in liner 30 and have plugged the well to a point where production from the well is hindered or, in some cases, halted.

In accordance with the invention and as illustrated in Figure 2, a flushing tube 42 of smaller diameter than the diameter of the production tubing 34 is run down the inside of the production tube 34 forming an annulus between the inside of the production tube 34 and the outside of the flushing tube 42. This annulus should preferably have at least as great a cross sectional area as the cross sectional flow area inside the flushing tube. Usually the flow area of the annulus is somewhat greater than the flow area of the flushing tube. It is desirable to extend the flushing tube 42 down the production tube 34 and into the upper portion of the sand located in the lower portion of the well. Fluid is then circulated to remove sand from the well. Fluid may be circulated down the flushing tube 42 and up the annulus between production tube 34 and flushing tube 42 or alternatively down the annulus and up the flow tube. The latter circulation arrangement is desired because it prevents possible bridging of sand in the annulus around the flushing tube in the production tube which could cause possible sticking of the flushing tube. A pump 44 is used to circulate the fluid used to remove undesirable sand from the well. The circulating fluid may be in the form of a foam or liquid, for example water or oil. The circulation of such fluid will often remove undesirable loose sand located immediately adjacent the outside of the casing as is illustrated by the void 48 adjacent liner 30.

After the undesirable sand has been removed from the well, it is sometimes desirable to pack the space exterior of the liner with new sand before injecting sand consolidation fluids. This is particularly true in cases where the liner has failed. Such liner failure commonly requires sand consolidation to permit further production from the zone. Prior to injecting such new sand down the flushing tube 42 the annulus 46 between the flushing tube 42 and the production tubing 34 is packed off by suitable means such as packing means 50. Closing this annulus promotes entry of fluids injected down the flushing tube 42 into the

producing formation 26 through slots 32 in production liner 30. A liquid slurry of sand, generally coarser than the formation sand, is now injected through pump 44 and down the flushing tube 42 and into formation 26 through the slots 32 in liner 30 to fill the void 48 adjacent the liner. The coarse sand is selected so that it will pass through the liner. After a predeterminable amount of coarse sand has been injected to fill the void behind the liner 30, injection of such slurry containing the sand is stopped. The formation is now ready for the sand consolidation operation.

As shown in Figure 4 the well is ready to first receive the permeability levelling material. In accordance with the preferred form of the present invention the permeability levelling material comprises a mixture of hydrocarbon oil, a cellulosic permeability levelling material and a polar organic compound capable of swelling the cellulosic material. This permeability levelling material is injected into a formation prior to the injection therein of a liquid resin useful to consolidate the formation. The permeability levelling material acts to balance fluid injectivity into the formation and to remove any water which may be in the formation in the vicinity of the well. Water removal is an important step in the consolidation process and must be done to insure adequate strength in the consolidated sand.

The cellulosic materials which may be employed in the practice of the invention are preferably the lower alkyl cellulose ethers, i.e. methylcellulose, ethylcellulose, propylcellulose, and butylcellulose, or benzylcellulose. Ethylcellulose is the highly preferred cellulose ether for use in the practice of the invention. Ethylcellulose is obtainable on the market under various trade names such as Ethocel. Ethylcellulose is an ether of cellulose formed by reaction of chloroethane with cellulose which has been reacted with a strong base. The ethylation of cellulose has been long known in the art. Preparation of ethylcellulose is possible by a variety of well known methods. Ethylcellulose is described and methods of making ethylcellulose are disclosed in an article in "Colloid Chemistry" J. Alexander, Vol. VI, p. 934, Reinhold, 1946.

Ethylcellulose is available as particulate material. A preferred form of ethylcellulose has a dry particle distribution such that about 90% of the particles by weight pass a 35-mesh screen and 10% by weight pass a 400-mesh screen. The median particle size is approximately 100-mesh. When mixed with a carrier fluid such as diesel oil containing a selected low molecular weight alcohol ethylcellulose will swell to a volume far exceeding its dry volume. Wet volume to dry volume ratios of between about 3 to 6 are suitable in accordance with the invention. A ratio of about 5.5 is considered optimum. While the swell ratio depends somewhat on time and

concentration of alkanol in the carrier fluid, a ratio within the above range will give good results.

Cellulose ethers used in the present invention may have a molecular weight of any value which permits pouring and mixing a composition of the invention without undue thickening. The cellulose is mixed with a hydrocarbon oil and a sufficient amount of a polar organic compound capable of swelling the cellulose at a desirable rate. The polar organic material is preferably a low molecular weight alkanol — for example, methanol, ethanol, propanol, butanol, pentanol and hexanol. The preferred polar organic compound for this use is 2-propanol. Controlled swelling of the ethylcellulose with a mixture of 2-propanol and diesel. Fifteen minutes or more contact with between 15–30% by volume 2-propanol in diesel causes swelling of the ethylcellulose to four to five times its original volume. The swelling properties do not change significantly with added time. The mixture is useful as a diverting agent when ethylcellulose is slurred in a mixture of between 15 and 30% by volume 2-propanol and diesel oil. Higher 2-propanol concentrations, i.e., greater than 35%, tend to dissolve the ethylcellulose, while lower 2-propanol concentrations, i.e., less than 15%, give insufficient swelling for adequate diverting in accordance with the present invention.

After such permeability levelling fluid has been injected into the formation the remainder of the sand consolidation fluids are injected down flushing tube 42 and through the slots 32 in liner 30 and into formation 26 to consolidate the sand around the well. The sand consolidation fluids are injected sequentially down the tube 42 and out into the formation so as to provide a permeable consolidation region around the well. In a preferred embodiment the sand consolidation fluid sequence includes a liquid resinous mixture curable to an infusible solid by treating with a curing agent; a liquid hydrocarbon; and a curing agent to convert the liquid resinous mixture to a solid state to bond the sand grains together.

In accordance with the invention cellulosic permeability levelling material is injected into unconsolidated strata prior to the injection of sand consolidation fluids to provide for levelling the permeability of the strata so that the later injected sand consolidation resin will tend to be more uniformly distributed in the strata.

The permeability levelling material is carried in a liquid carrier which also acts as a water scavenger to remove water from the formation to better prepare it for the resin which follows. Thus the permeability levelling fluid which is injected is a mixture of a hydrocarbon oil, a selected polar organic compound preferably a low molecular weight alkanol and a fluid cellulosic levelling additive. A mixture of the above type is injected into the unconsolidated interval prior to the injection of resin therein. The low molecular weight alkanol acts as a water scavenger and in addition assists in promoting the action of the permeability levelling additive.

The preferred form of the invention provides for injecting into the formation prior to the injection of the consolidation resin a mixture of 100 parts by volume of a hydrocarbon oil, from 15 to 35 parts by volume of a selected low molecular weight alkanol and 0.005 to 0.25 parts by weight of a permeability levelling cellulosic compound per 100 parts by weight of the above mixed liquids. The above noted mixture is an effective diverting agent useful to promote relatively uniform placement of sand consolidation liquids in a formation composed of strata having different permeability. In addition, the mixture is an effective water scavenger useful to remove water from the formation prior to the resin injection step of a sand consolidation operation. The injection of this mixture is followed by the injection of a sand consolidation resin and a suitable curing agent for the resin to provide a permeable consolidated formation in the vicinity of the well.

A field test was conducted in accordance with the present invention. A one-inch tubing was run through a 2-3/8" production tubing to the 11' of production perforations between 7311 and 7336' depths in a well. The production interval was sand packed with 50 cubic feet of fine sand prior to preparing for consolidation. The permeability levelling material injected in this field test comprised 0.07 pounds of ethylcellulose diverting agent per barrel of an 80–20 mixture of diesel oil and 2-propanol. This material was injected to prepare the fluid injectivity profile of the formation. Consolidation fluids were then injected into the formation. The one-inch tubing was periodically reciprocated through the production interval during placement of preparation and consolidation fluids. Injection data are shown in Table I.

TABLE I

Cumulative Time, Minutes	Cumulative Volume, Barrels	Injection Rate Barrels/Minute	Surface Pressure psi
0	0 Permeability Leveling Material	0	1500
10	10 Permeability Leveling Material	1	1500
31	30 Permeability Leveling Material	1	1600
41	40 Permeability Leveling Material	1	1420
125	110 Permeability Leveling Material	2	1500
138	10 Resin	.75	1300
150	5 Permeability Flush	1	1300
185	20 Permeability Flush	.25	1150
202	22 Permeability Flush	1	1150
234	28 Activator	1	1200

The field test is believed to have been successful in uniformly consolidating the formation through a one-inch tubing.

5 WHAT WE CLAIM IS:—

1. A method of removing sand from a well penetrating an unconsolidated formation and preventing further sanding of the well, the well having a casing and a production tube located therein, without removing the production tube from the well, said method comprising the steps of packing off the annulus between the well casing and the production tube, positioning a flushing tube inside the production tube to form an annular passage between the flushing tube and production tube circulating a fluid in the flushing tube and said annular passage to remove sand from the well, closing off the annular passage, injecting a cellulosic permeability levelling material down the flushing tube and into said formation to assist in levelling the injection profile of said formation, thereafter injecting one or more

sand consolidation fluids down the flushing tube and into the formation to consolidate sand in the formation and thereby prevent further sanding of the well, and then removing the flushing tube from the production tube.

2. A method according to Claim 1, wherein the flushing tube extends beyond the lower end of the production tube and into that part of the well adjacent to the unconsolidated formation.

3. A method according to Claim 1 or 2, wherein a slurry of coarse sand in a liquid is passed down said flushing tube and into the formation prior to injecting said cellulosic permeability levelling material into said formation.

4. A method according to Claim 1, 2 or 3, wherein the sand consolidation fluids are sequentially passed down the flushing tube and include a liquid resinous material curable to an infusible solid state by treating with a curing agent, a liquid hydrocarbon, and a curing agent to convert the liquid resinous mixture

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to the infusible solid state.

5. A method according to Claim 1, 2, 3 or 4 wherein the cellulosic permeability levelling material comprises a mixture of 100 parts by

5 volume of hydrocarbon oil, from 15 to 35 parts by volume of a low molecular weight alkanol and from 0.005 to 0.25 parts by weight of a cellulosic material per 100 parts by weight of the hydrocarbon oil and alkanol.

10 6. A method according to Claim 5, wherein the cellulosic material is ethylcellulose.

7. A method according to Claim 5 or 6, wherein the alkanol is 2-propanol.

15 8. A method according to any preceding claim, wherein the fluid circulated in the flushing tube and annular passage is in the form of a foam.

10. A method according to any one of claims

1 to 7, wherein the fluid circulated in the flushing tube and annular passage is in the form of a liquid.

11. A method according to claim 10, wherein the liquid is water or oil.

12. A method of consolidating an unconsolidated formation penetrated by a cased well having a production tube located therein without removing said tube from the well, substantially as hereinbefore described with reference to the accompanying drawings.

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